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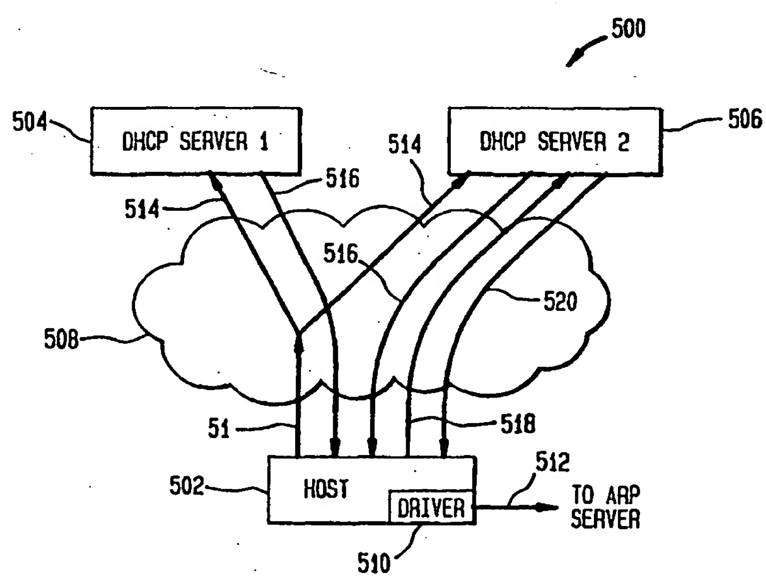

(57) Abstract

Disclosed is a method for configuring logical IP subnetworks which simultaneously supports autoconfiguration and mobile hosts (804). These capabilities are supported at the datalink layer, rather than at the network layer, as in protocols currently in use or under discussion in the Internet community and ATM Forum. The method may be used to reduce the consumption of network resources, improve delay times, and permit enhanced privacy for mobile hosts. The invention provides a method for connecting a host (502) to logical LAN, such as a logical Internet Protocol subnet when the host is attached to a datalink layer network (508) (such as an ATM network) for a LAN to which it is being physically connected, the host is assigned a network layer address (such as an IP address) identifying the desired logical LA

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LOGICAL IP ADDRESS ASSIGNMENT IN ATM LAN

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to communications networking and, more particularly, to a method for configuring logical Internet Protocol (IP) subnetworks over Asynchronous Transfer Mode (ATM) based local area networks which support autoconfiguration and mobile hosts.

Discussion of Related Art

Fig. 1 shows a conventional communications network 100. Illustratively, the communications network is the Internet. The Internet is composed of a wide area network (WAN) 110 which includes three backbone networks A, B, and C. Connected to the backbone networks A, B, and C of the WAN 110 are access points a,b,c, and d. Connected to each access point a,b,c, and d are subnetworks L1, L2, L3, L4, L5, and L6 which may be local area networks (LANs) or stand alone computers. A backbone network A,B, or C is a "transit" network which typically transfers data from one access point a,b,c, or d to another access point. (A Glossary of Acronyms is attached as Appendix A.)

Each backbone network includes one or more routers. The routers r1-r15 do not originate or terminate communicated data in an ordinary communication. Rather, the routers r1-r18 receive communicated data from one node and transmit the data to another node. Each access point a, b, c, and d provides access to the WAN 110 for the connected subnetworks L1-L6. The access points a,b,c, and d receive communicated data from the subnetworks and transmit the data to another access point a,b,c, and d via the WAN 110. Likewise, the access points receive from the WAN 110 data destined to a subnetwork and transmit such data to the appropriate destination subnetwork. The subnetworks include one or more hosts h1 - h10. Hosts may originate or terminate data communications.

Logical networks or virtual LANS are becoming increasingly important. In a logical network, a particular set of arbitrary hosts may be selected as a closed group. That is, hosts physically located in different subnetworks may be logically connected as a single virtual LAN. This closed group is administered as a logical LAN independent of other groups of hosts. In the Internet arena, these logical LANs are referred to as Logical IP Subnets (LIS). Typically, an LIS requires manual configuration of each host by LAN administrators of each LAN where a logical LAN host is physically located.

Fig. 2 shows a "Classical IP over ATM" network 200. This protocol is described in M. Laubach, *Classical IP and ARP over ATM*, Request for Comments 1577, January 1994. The content of this document is incorporated herein by reference.

Hosts H1, H2, H3, H4, and H5 and routers R1 and R2 are connected to the ATM network 202. The hosts H1-H5 and routers R1-R2 are organized into logical IP subnetworks (LISs). In this illustration, hosts H1 and H2 and router R1 are organized into a first LIS 204, hosts H3 and H4 and routers R1 and R2 are organized into a second LIS 206 and host H5 and router R2 are organized into a third LIS 208. An LIS defines an administrative domain. Direct connections may only be established among hosts within the same LIS. For example, in the second LIS 206, direct connections may be established only between hosts H3 and H4, even if these hosts are physically connected to the same ATM network to which other hosts are connected.

Ordinarily, in order to communicate between hosts in different LISs, e.g., host H1 in the first LIS 204 and host H5 in the third LIS 208, multiple connections must be established. For instance, host H1 may establish a connection with the router R1. The router R1 may establish a connection with the router R2. The router R2 may establish a connection with host H5. ATM packets then traverse a path from host H1 to router R1, to router R2, to host H5.

Current and proposed Internet Protocols (IP) support both autoconfiguration and mobile IP. These features are described below.

Autoconfiguration

Currently, autoconfiguration of an IPv4 host is achieved through either the Dynamic Host Configuration Protocol (DHCP) or the Bootstrap Protocol (BOOTP). Fig. 3 illustrates an IP network 300 performing autoconfiguration according to the DHCP protocol. A host 302 sends to one or more DHCP servers 304A, 304B (which may be physically located, for example, in access points connected to the subnetwork in which the host is physically located) an "address request (DHCP discover)" message (line 306). In response, each DHCP server 304 receiving the request proposes a host's 302 IP address via an "address assignment (DHCP offer)" message (line 308). The host 302 selects an appropriate address from these responses and returns a "DHCP request" message (line 310) to the DHCP server 304A that supplied this address and other connected DHCP servers 304B. That DHCP server then reserves this IP address, and sends a "DHCP ack" message (line 312) back to the requesting host.

In this method, a DHCP server has no predefined table of the relationship between hosts and IP address. The DHCP server is assigned a number of IP addresses from a network administrator. The DHCP server dynamically determines the address assignments by assigning a next available IP address from those addresses assigned from the Network Administrator. In contrast, the BOOTP protocol is not dynamic. The BOOTP protocol is for hosts not having a hard-drive (a diskless host). A network manager sets a translation table between the host's ID or MAC address and its IP address on the BOOTP server. When a host requests an address (e.g., when the host is added to the network), the host informs the BOOTP server of its ID or MAC address. The BOOTP server then provides the host with an IP address which has already been set on the translation table prior to the address request.

Autoconfiguration under IPv6 differs from IPv4 as follows. Both stateless autoconfiguration and stateful configuration are supported. Stateless autoconfiguration allows a host to form a link-local or inter-link scope address using information local to the host or based on prefixes advertised by the routers. In contrast, stateful autoconfiguration needs an autoconfiguration server such as a DHCP server, and the server gives an IP address of a host which requests its IP address.

Thus, current autoconfiguration methods determine the relationship between a location (such as a MAC address or link-local address) and an IP address. Current autoconfiguration methods, however, do not establish LISs. This is because the preassigned addresses are automatically assigned by the server from preassigned addresses supplied by the Network Administrator without regard to the desired logical address of the requesting host.

Mobile IP

IP allows a host to move from one subnet to another subnet and still receive communications addressed to it. This is called mobile IP. Fig. 4 illustrates an IP network 400 performing mobile IP. A number of subnetworks 402, 404, 406 are connected over the Internet via routers 408, 410. Assume a first host 412 wishes to send a communication to a second, mobile host 414. The mobile host has a home agent 416 connected to its home subnetwork 404. Currently in mobile IP, a mobile host 414 records its original IP address (here, in subnet 2 404) and moves to another subnetwork 406. The mobile host 414 receives a "care-of-address" at its new subnet 406 and informs its home agent 416, located at the mobile host's original subnet 404 of its care-of-address (line 420).

When a host 412 sends a packet 418 to the mobile host 414, the packet is delivered to the home agent (line 422). When the home agent 416 receives the packet destined to the mobile host 414, it captures the packet and encapsulates the original packet 418 into a new packet 424 addressed to the care-of-address. The home agent 416 sends this encapsulated

packet 424 to the mobile host 414 at the care-of-address (line 426).

Thus, current mobile IP methods determine the relationship between the care-of-address, which is an IP address involving its current location information and its home address.

Both mobile IP and autoconfiguration manage the relationship between a host's physical and logical location. The current autoconfiguration method does not establish LISs. The current IP mobility method makes inefficient use of network resources and bandwidth.

SUMMARY OF THE INVENTION

The present invention provides a method for configuring logical LANs, such as IP subnets. The method simultaneously supports autoconfiguration and mobile hosts. These capabilities are supported at the datalink layer, rather than at the network-layer, as in protocols currently in use or under discussion in the Internet community. The inventive method may be used to reduce the consumption of network resources, improve delay times, and permit enhanced privacy for mobile hosts.

The present invention provides a method for connecting a host to a logical LAN. When the host is attached to a datalink layer for a LAN to which it is being physically connected, the host is assigned a network layer address identifying the desired logical LAN.

In an ATM-LAN, for example, both location information (e.g., ATM addresses) and logical addresses (e.g., IP addresses) may be treated from a logical network perspective. This logical network configuration on an ATM-LAN may be classified into three categories:

(1) autoconfiguration;

(2) semi-autoconfiguration; and

(3) host mobility.

Autoconfiguration in the present invention is the automatic assignment of a host's IP address when the host is attached to the network. An autoconfiguration server (ACS)

may provide the address assignment.

In semi-autoconfiguration, a host can offer or declare its preferred IP subnet in some fashion when it is attached to the network. Semi-autoconfiguration has two distinct subtypes --select-type and request-type. In select-type semi-autoconfiguration, the user may select an IP address which establishes the host in a desired LIS. In request-type semi-autoconfiguration, the host specifies a particular IP subnet ID in an initial IP address request.

Two types of host mobility are disclosed: a simple mobility solution and a privacy enhanced mobility. In an ATM-LAN, a mobile host does not require a care-of-address (IP address). A host located anywhere may belong to any LIS it wants to join if the LIS is defined on the ATM-LAN. This simple solution allows the sending host to determine the physical location (ATM address) of the receiving host. In the privacy enhanced method, the host registers its home location at the switch connected to its new location. The switch at the new location informs the first switch that the host is located at the new location. When the first switch receives a communication addressed to the host, it generates a crank-back packet indicating the host's new location and the communication is resent addressed to the switch connected to the new location. Because the sending host never learns the mobile host's location (only the connected switch learns of the new location), the mobile host's location remains private.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described with reference to the following figures:

Fig. 1 illustrates a conventional communications network;

Fig. 2 illustrates a classical IP over ATM network;

Fig. 3 illustrates a prior art method of autoconfiguration;

Fig. 4 illustrates a prior art method of mobile IP;

Fig. 5 illustrates autoconfiguration according to a preferred embodiment of the present invention;

Fig. 6 illustrates select-type autoconfiguration according to a preferred embodiment of the present invention;

Fig. 7 illustrates request-type autoconfiguration according to a preferred embodiment of the present invention;

Fig. 8 illustrates privacy-enhanced mobility according to a preferred embodiment of the present invention;

Fig. 9 illustrates is a simplified diagram showing an advantage of the inventive privacy enhanced mobility method;

Fig. 10A illustrates a linear network topology;

Fig. 10B illustrates a rectangular mesh network topology;

Fig. 10C illustrates a binary tree network topology;

Fig. 11 is a graph illustrating the resulting estimates of the average reduction in hop counts in the topologies in Figs. 10A - 10C using the inventive method;

Fig. 12 is a graph illustrating the resulting estimates of the maximum reduction of hop counts in the topologies in Figs. 10A - 10C using the inventive method;

Fig. 13 is a graph illustrating the percentage decrease of network bandwidth used to communicate between the hosts using the inventive method; and

Fig. 14 is a graph illustrating the percentage reduction of the ratio of traffic between the first hop link and the total network using the inventive method.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

I. Overview of the Invention

Autoconfiguration and mobile IP may be considered methods relating location information (e.g., ATM addresses) and logical addresses (e.g., IP addresses). In an ATM-LAN, both ATM and IP addresses may be treated from a logical network perspective. The present invention permits a host to be connected to a logical LAN, such as an LIS, by connecting the host to a datalink-layer protocol network, such as an ATM network, and at the time of connection, assigning to the host a network layer address, such as an IP address, identifying the desired logical LAN. This logical network configuration on an ATM-LAN may be classified into three categories:

(1) autoconfiguration;

(2) semi-autoconfiguration; and

(3) host mobility.

A. **Autoconfiguration**

Autoconfiguration in the present invention is the automatic assignment of a host's IP address when the host is attached to the network. An autoconfiguration server (ACS) may provide the address assignment.

B. **Semi-autoconfiguration**

Semi-autoconfiguration in the present invention is a procedure in which a host may request an IP address from an ACS and request that this address include a particular IP subnet ID. Suppose, for example, that IP subnet IDs are assigned by an enterprise (such as a business or other enterprise) according to the host's user's department (e.g., sales, accounting, etc.). The host may request that its IP address include an IP subnet ID belonging to the appropriate department. Two types of semi-autoconfiguration are described: select-type semi-autoconfiguration and request-type semi-autoconfiguration.

In select-type semi-autoconfiguration, a user may receive proposed IP addresses from a number of ACSs. The host may manually select the IP address having the appropriate IP address for the IP subnet in which it desires to be included and other optional information, such as domain name.

In request-type semi-autoconfiguration, an IP address request message sent to an ACS includes some optional information ("hints") that describes the IP subnet ID belonging to the group which the host wants to join.

C. **Host Mobility**

In the present invention, host mobility may be provided by the arbitrary mapping of IP and ATM addresses. The host may record its IP address (and other information such as the IP addresses of its file servers) and may move to a different, arbitrary location while retaining its IP address. Unlike mobile IP described above, the mapping between IP and ATM addresses is arbitrary. Therefore, no care-of-address is needed and the original IP address may be used.

II. Realization of LIS Over ATM

Preferred methods are described for realizing LIS over ATM according to the present invention which support autoconfiguration, semi-autoconfiguration, and host mobility.

A. Autoconfiguration

A preferred method for performing autoconfiguration is illustrated in Fig. 5. A network 500 includes a host 502 connected to one or more servers, such as DHCP Server 1 504 and DHCP Server 2 506, via an ATM network 508. The host 502 includes a network driver device 510, which transfers data between its network interface (i.e., ATM interface) and its operating system and its application program. Each server registers its ATM address to an ATM group address of an IP autoconfiguration server (ACS). After this, hosts may access an ACS via the pre-assigned ATM group address.

A host may be connected to a logical LAN, such as an LIS when it is connected to a network on the datalink-layer (e.g., ATM, Ethernet, MAC). At the time the host is connected to the datalink layer, if the host was previously connected to a logical LAN, the host may be assigned a network layer address, such as an IP address, identifying it as part of a desired logical LAN.

As seen in Fig. 5, the method is preferably performed in an ATM-LAN as follows:

1. One or more ACSs are deployed on an ATM Group address assigned exclusively to the IP autoconfiguration service within the desired ATM-scope (e.g., the ATM protocol region of the network).
2. When the host 502 is attached to the ATM-scope, the host contacts the ACSs via the driver (line 512). This may be done as follows:
   a. In IPv6, the host 502 accesses an ACS by sending an IP "address request" to an IP multicast address for an ACS with a certain IP-scope, such as intra-link IP-scope (e.g., the IP protocol region of the network). The

device driver 510 translates the message into an ATM call set-up message destined to the ACS in the ATM-scope using the ATM group address assigned to the IP autoconfiguration service.

b. In IPv4, the host accesses an ACS using a restricted IP broadcast address, with the User Datagram Protocol (UDP) port number reserved for DHCP service. The driver 510 deduces that the host is attempting to send a packet to the ACS, and translates the message into an ATM protocol call set-up message destined to the ACS in the ATM-scope.

3. The call is set up and the message reaches all ACSs within the ATM-scope (line 514).

4. Each ACS 504, 506 proposes a particular IP address for the host 502 (line 516). To connect the host to a desired LIS, an ACS may assign to the host an IP address having a subnet ID previously used by the host.

5. The host 502 automatically and without user input selects one of the proposed IP addresses according to a predetermined protocol. The host 502 may select the IP address with the subnet ID previously used by the host. The host then sends a "DHCP request" message to the ACS server that proposed the selected address (line 518).

6. The ACS server 506 sends "DHCP ack" signal to the host 502 (line 520).

7. The host 502 uses the selected IP address as its own. The host 502 is registered with an Address Resolution Protocol (ARP) server. (ARP is a protocol for translating an IP address into a datalink layer address such as an ATM, MAC, or Ethernet address.) This registration may be done in a number of ways. A first way is for the host to register itself with the ARP server. A second way

is when the ACS assigns an IP address to a host, the ACS registers the relationship between the new IP address assignment and the ATM address to the ARP server. A third way is for the ARP server to poll each ACS in predetermined time intervals.

An example of the inventive autoconfiguration method is as follows. Assume a host is to be connected to the Internet. The host is a workstation for a salesperson in a sales department of a company having sales offices spread over a large geographic area. The host previously had an IP address connected to an LIS of hosts in the sales department of the company. The inventive method provides for the selection of an IP address which will connect the host to an LIS between hosts in the sales department of the company, regardless of the hosts' physical location. The inventive method provides autoconfiguration which may establish an LIS without manually configuring each host to be included in the LIS.

B. **Semi-Autoconfiguration**

In semi-autoconfiguration, a host can offer or declare its preferred IP subnet in some fashion when it is attached to the network. Semi-autoconfiguration has two distinct subtypes -- select-type and request-type.

1. **"Select-Type" Semi-Autoconfiguration**

A preferred method for performing select-type semi-autoconfiguration according to the present invention is illustrated in Fig. 6. A network 600 includes a host 602 connected to one or more servers, such as DHCP Server 1 604 and DHCP Server 2 606, via an ATM network 608. The host 602 includes a network driver device 610, which transfers data between its network interface (i.e., ATM interface) and its operating system and its application program. Each server registers its ATM address to an ATM group address of an IP autoconfiguration server. After this, hosts may access an autoconfiguration server via the pre-assigned ATM group address. In select-type autoconfiguration, the host requests an address from at least one server on the datalink layer. Each server receiving the request proposes a network layer

address. The user manually selects one of the proposed network layer addresses according to the address of the desired logical LAN.

As seen in Fig. 6, the method is preferably performed in an ATM-LAN as follows:

1-4. The method is the same as described in relation to Fig. 5 (lines 612 - 616).

5. The host user manually selects any of the proposed IP addresses offered. The host then sends a "DHCP discover" message to the ACS server that proposed the selected address (line 618).

6. The ACS server 606 sends a "DHCP ack" message to the host 602 (line 620).

7. The host 602 uses the selected IP address as its own and is registered with an ARP server.

In this type of semi-autoconfiguration, the user may select an IP address which establishes the host in a desired LIS. Assume that the host is a workstation for a salesperson in the company described above. This salesperson may select a proposed IP address which connects the host to the desired LIS (for example, an LIS connecting geographically separated hosts of a company's sales department).

2. <u>"Request-Type" Semi-Autoconfiguration</u>

A preferred method for performing request-type semi-autoconfiguration is illustrated in Fig. 7. A network 700 includes a host 702 connected to one or more servers, such as DHCP Server 1 704, DHCP Server 2 706, and ARP server 708 via an ATM network 710. The host 702 includes a network driver device 712, which transfers data between its network interface (i.e., ATM interface) and its operating system and its application program. Each server registers its ATM address to an ATM group address of an IP autoconfiguration server. After this, hosts may access an autoconfiguration server via the pre-assigned ATM group address.

In request-type semi-autoconfiguration, the host 702 specifies a particular logical LAN (e.g., IP subnet ID) in the initial network layer address request. To do this, the host

preferably determines the network layer (e.g., IP) address of an ACS in the desired network layer logical LAN (e.g., IP subnet) and establishes a connection with this ACS. By resolving the network layer address to the datalink (e.g., ATM) address, the host contacts the appropriate server. The server then assigns a network layer address to the host.

As seen in Fig. 7, in IPv4, the method is preferably performed in an ATM-LAN as follows:

1. The host 702 determines the IP subnet address for the desired LIS and generates an "address request" message having a destination IP address which is the IP broadcast address for the desired logical IP subnet and whose port number is that of the ACS.
2. The device driver 712 creates an ARP request packet 714 having a resolving IP address that is the IP broadcast address of the subnet and an option field indicating the ACS service, depending on the port number supplied. This message is sent to the ATM group address assigned to the ARP service (line 716).
3. The ARP server resolves the ATM address and recognizes the IP subnet and that ACS service is requested, and replies with the ATM group address for the appropriate ACS performing the autoconfiguration service (line 718).
4. The host then sends a "DHCP discover" message to the ACS server indicated by the ARP server (line 720).
5. The ACS server then reserves an IP address for the host, and sends a "DHCP offer" message (line 722) back to the requesting host.
6. The host then sends a "DHCP request" message to the ACS server (line 724).
7. The ACS server then sends a "DHCP ack" message to the host (line 726).
8. The host 702 uses the selected IP address as its own. The host 702 is registered with an Address Resolution Protocol (ARP) server.

As also seen in Fig. 7, in IPv6, the method is preferably performed in an ATM-LAN as follows:

1. The host 702 generates an "address request" message having a destination IP address which is a well-known multicast address assigned to the ACS service. It uses the desired IP subnet ID as a region address for a source route using the routing header extension of IPv6. "Source routing" is included in the IETF IPv6 specification. In "source routing", the sending host declares the intermediate nodes the packet will transverse to arrive at the destination.)

2. The device driver 712 recognizes the destination IP address is a region address, the device driver looks up the next address pointed by the routing header. If this address is the well-known ACS multicast address, it creates an ARP request packet 714 and sends it as in the IPv4 case.

3-6. These steps are the same as for select-type semi-autoconfiguration.

In either IPv4 or IPv6, the host requests the destination IP address for the LIS to which it desires to be connected. For example, if the host desires to be connected to an LIS of salesperson's workstations over a geographic area, the host requests the IP address of that LIS.

C. **Host Mobility**

Two types of host mobility are discussed. First, a simple mobility solution is described. Second, privacy enhanced mobility is described.

1. **Simple Solution**

In an ATM-LAN, a mobile host does not require a care-of-address (IP address). A host located anywhere may belong to any LIS it wants to join if the LIS is defined on the ATM-LAN.

Because each mobile host knows its own IP address from its configuration into the network, mobility corresponds to a special case of "request-type" semi-autoconfiguration described above. Here, however, the mobile host need not get

its IP address from an ACS, but only needs to register its new location information (ATM address) with the ARP server for its home IP subnet. Typically, a mobile host knows the ATM address of the ARP server for its home subnet, so this registration may be easily performed. Communications directed to the mobile host will be sent to the home location ARP server and forwarded to the new location.

2. <u>Privacy Enhanced Solution</u>

The simple solution allows the sending host to determine the physical location (ATM address) of the receiving host. A sending host may determine the physical location of a mobile host from the mobile host's resolved ATM address. In the prior known mobile IP method, described above, the mobile host's location remains private because all packets destined for the mobile host are received by the home agent and forwarded to the mobile IP host at the care-of-address. Another problem associated with the simple solution is that if the sending host has mobile host location information in its cache memory, it must purge this information and resolve the mobile host's address each time it sends packets to the mobile host because the mobile host's location may have changed.

If a mobile host wishes to maintain the privacy of its location, and to prevent the constant recording and purging of the sender's cache memory, the mobility solution described above should be modified. As described below, these modifications are an enhancement of ATM Forum specifications and may be implemented without significant changes to ATM protocol.

A preferred method for privacy enhanced host mobility is illustrated in Fig. 8. A network 800 includes a sending host 802 and a mobile host 804 connected over a network via a number of switches 806 - 812. Assume the mobile host moves from a first location (such as a home location) connected to switch q 810 to a new location connected to switch p 812. The method includes the step of the mobile host registering its ATM home address with an attached ATM switch.

As seen in Fig. 8, this method preferably performed in an ATM-LAN as follows:

1. The mobile host 804, having ATM address = q1 and IP address = r1, moves from switch q 810 to switch p 812 (dashed line 820). The mobile host registers its home location (ATM address = q1) with switch p 812. Note that the ATM and IP addresses are the same as before the mobile host moved.
2. Switch p 812 informs switch q 810 of the mobile host's new location (line 822). Switch p 812 accommodates this home address.
3. The sending host 802 tries to set up a call to the mobile host 804. The mobile host's resolved ATM address for the IP address (r1) via the ARP server remains q1 and the call set-up sends a packet 814 having a destination q1 (line 824).
4. The call set-up reaches switch q 810. The switch q 810 knows that the mobile host has moved and switch q generates a crank back packet 816 indicating that the mobile host's new location is DTL = P. This DTL source routing packet is sent to the switch 806 connected to the sending host 802 (line 826). This switch 806 is the "first hop" switch.
5. The first hop switch 806 resends the message in a packet 818 with DTL = P (line 828).
6. Switch p 812 receives the message and forwards it to the mobile host 804 (line 830).
7. The mobile host 804 handles the remaining call processing.

If a mobile host is connected to an LIS comprising of geographically separated hosts, the host may move to different locations and still receive communications from other hosts. That is, if a salesperson connected to the LIS described above is out of his office at a sales call, the salesperson may connect the mobile host (such as a laptop or palmtop computer or personal digital assistant) to a geographically removed subnetwork. Even though the host is located at a different

geographic location having a different ATM address (e.g., connected to a different ATM switch), the host may still receive communications directed to the same IP address using the inventive method.

Fig. 9 illustrates the advantage of the inventive method in a simplified manner. As seen in Fig. 9, the inventive method establishes a direct connection (line 902) between a sending host 904 and a mobile host 906 via switch 910. The Mobile IP method described above establishes a lengthy connection (line 912) through several switches 914 to the home agent 916 and through several more switches (seen in Fig. 9 as the same switches 914) to the mobile host 906.

The inventive method has several advantages:

- The method makes only minor changes to standard ATM-over-IP methods. That is, both the crank back and DTL source routing are currently under discussion for inclusion as part of the P-NNI (Private-Network Node Interface) specification. Thus, the protocol extension to perform this method is easy to implement.
- The other network components, such as the ARP server, can be used without any change.
- There is no need to define multiple IP addresses for a mobile host.
- Because the sending host never learns the mobile host's location (only the connected switch learns of the new location), the mobile host's location remains private.
- Routing information is distributed throughout the network, thus distributing the call-processing over a number of network components. Preferably, only home ATM switches manage the information about the locations of mobile hosts.
- Optimal virtual channel (VC) routing is achieved. An ATM connection to the mobile host can use an optimal route. This is described below.
- The method supports multi-protocol mobility. That is, the method supplies transparent mobility capability for IP network layer protocols and other network layer protocols, as well. For example, this method may be used in IPX netware.

III. Estimated Performance of the Privacy Enhanced Mobility Method

The inventors performed network simulations using the inventive privacy enhanced mobility method. The simulations were performed on three network topologies illustrated in Fig. 10: a linear topology (Fig. 10A), a rectangular mesh topology (Fig. 10B), and a binary tree topology (Fig. 10C). The efficiency of the method was measured with respect to the following criteria: (1) hop counts (a hop count is the number of switches traversed to deliver a message. The lower the hop count, the greater the routing efficiency); (2) total network bandwidth consumed; and (3) traffic distribution.

The simulations were performed over all possible cases where an arbitrarily located mobile host moves to an arbitrarily new location, and an arbitrarily located sending host communicates with the mobile host.

First, hop counts between a sending and a receiving mobile host were estimated for the prior art mobile IP and the inventive method. The inventors determined the hop count required to establish an ATM connection between the mobile host and a host attached to an arbitrary location in the network. (Note: the hop count of both the ATM switch and the home agent in the IP mobile case is considered one hop; the effect of propagation delay on the link between switches and hosts is ignored.) It is assumed in the mobile IP case that the home agent is attached to the ATM switch to which the mobile host was originally attached. Thus, in this model, the hop count is incremented by one each time a switch or home agent must process a cell.

Fig. 11 is a graph illustrating the resulting estimates of the average reduction in hop counts for all three topologies. As seen in Fig. 11, the inventive method reduces the hop counts for each topology by over 50% compared to the mobile IP approach. Note that as the network scale (e.g., the number of hosts, switches, etc.) grows, the hop reduction approaches 50%. (Currently, a typical virtual LAN is not, however, a large-scale network.)

Fig. 12 is a graph illustrating the resulting estimates of the maximum reduction of hop counts provided by the inventive method compared to mobile IP. The ratio of the worst case scenarios for the methods approaches 100% as the network scale increases. This is because the mobile IP method can force communication to take an extremely redundant route.

The hop count reduction is significant because it reduces the propagation delay between hosts. Moreover, in an ATM environment it is common to reserve communication resources in advance to guarantee QoS ("Quality of Service"). To guarantee QoS, resources must be reserved at every hop. Thus, reducing the number of hops reduces the amount of network resources to be reserved for communication between the hosts.

The efficient routing (i.e., reduced hopping) results in decreased network bandwidth use. This is illustrated in Fig. 13. Fig. 13 is a graph illustrating the percentage decrease of network bandwidth used to communicate between the hosts. The inventive method results in a 50% reduction in total network bandwidth for each topology regardless of network scale. (Note: no data is available for the binary tree

topology.)

A disadvantage of the known mobile IP method is that communications traffic is concentrated near the mobile host's home agent. This is because it receives incoming and sends outgoing traffic to deliver the message to the mobile host. Fig. 14 is a graph illustrating the percentage reduction of the ratio of traffic between the first hop link and the total network. This graph shows the ratio of traffic on the links one hop away from the mobile host's home agent and on the entire network. For small networks, a very large fraction of total traffic is concentrated near the home agent. For all networks, traffic is concentrated at links closest to the home agent. The proposed method reduces the overall amount of traffic and spreads the concentration of traffic away from the home agent more effectively than the prior art mobile IP method. (Note: no data is available for the binary tree topology.)

IV. Conclusion

A simple method for providing LISs in an ATM environment is described. This method provides for autoconfiguration, semi-autoconfiguration, and host mobility with enhanced privacy. Autoconfiguration and semi-autoconfiguration permit the establishment of LISs. The host mobility results in reduced hop count, reduced bandwidth usage, and reduced traffic concentration near the mobile host's home agent. The inventive method may be implemented with minor extensions to existing or proposed network layer protocols, such as IPv6, P-NNI, and UNI (User-to-Network Interface).

The embodiments of the invention described are illustrative only. Numerous alternative embodiments may be devised by those skilled in the art without departing from the scope of the following claims. For example, although this invention is described with respect to ATM protocol datalink layer, a person skilled in the art recognizes that other datalink technologies are also available. For example, frame relay may be used.

APPENDIX A

Glossary of Acronyms

ACS	Autoconfiguration Server
ARP	Address Resolution Protocol
ATM	Asynchronous Transfer Mode
BOOTP	Bootstrap Protocol
DHCP	Dynamic Host Configuration Protocol
ID	Identifier, Identification
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
LAN	Local Area Network
LIS	Logical IP Subnets
MAC	Media Access Control
P-NNI	Private-Network Node Interface
QoS	Quality of Service
UDP	User Datagram Protocol
UNI	User-to-Network Interface
VC	Virtual Channel

We claim:

1. A method for connecting a host to a logical Local Area Network (LAN), comprising the steps of:

   a. attaching the host to a datalink-layer for a LAN to which the host is being physically connected; and

   b. at the time the host is connected to the datalink layer, assigning to the host a network layer address identifying a desired logical LAN.

2. The method of claim 1, wherein the step of assigning further comprises automatically assigning the network layer address.

3. The method of claim 2, wherein the steps of attaching and assigning further comprise:

   a. the host requesting an address from at least one server at a datalink layer;

   b. each server receiving the request proposing a network layer address; and

   c. the host automatically selecting one of the proposed network layer addresses according to the address of the desired logical LAN.

4. The method of claim 3, wherein the step of proposing includes proposing a network layer address identifying a logical LAN to which the host was previously connected.

5. The method of claim 1 wherein the step of assigning

further includes semi-automatically assigning the network layer address.

6. The method of claim 5, wherein the steps of attaching and assigning further comprise:

a. the host requesting an address from at least one server at a datalink layer;

b. each server receiving the request proposing a network layer address; and

c. a user of the host manually selecting one of the proposed network layer addresses according to the address of the desired logical LAN.

7. The method of claim 5, wherein the steps of attaching and assigning further comprise:

a. the host determining a network protocol subnetwork address of a desired logical LAN;

b. using the network protocol subnetwork address, the host contacting a server in the desired logical LAN;

c. the server assigning a network layer protocol address to the host.

8. A method for establishing a logical Internet Protocol Subnetwork (LIS) using asynchronous transfer mode (ATM) protocol, the method comprising:

a. attaching the host to an ATM layer of a network to which the host is being physically connected; and

b. at the time the host is connected to the ATM layer,

assigning to the host an IP address identifying a desired LIS.

9. The method of claim 8, wherein the step of assigning further includes automatically assigning the Internet Protocol (IP) address.

10. The method of claim 9, wherein the steps of attaching and assigning further comprise:

a. the host requesting an IP address from at least one server at the ATM layer;

b. each server receiving the request proposing an IP address; and

c. the host automatically selecting one of the proposed IP addresses according to the address of the desired LIS.

11. The method of claim 10, wherein the step of proposing further includes proposing an IP address identifying an LIS to which the host was previously connected.

12. The method of claim 8, wherein the step of assigning further includes semi-automatically assigning the Internet Protocol (IP) address.

13. The method of claim 12, wherein the steps of attaching and assigning further comprise:

a. the host requesting an address from at least one server at the ATM layer;

b. each server receiving the request proposing an IP address; and

c. a user of the host manually selecting one of the proposed IP addresses according to the address of the desired LIS.

14. The method of claim 12, wherein the steps of attaching and assigning further comprise:

a. the host determining an IP subnetwork address of a desired LIS;

b. using the IP subnetwork address, the host contacting a server in the desired LIS;

c. the server assigning an IP address to the host.

15. A method for automatically configuring a host to a logical Internet Protocol Subnetwork (LIS), comprising the steps of:

a. the host sending an address request to at least one server attached to an asynchronous transfer mode (ATM) network;

b. each server receiving the request sending to the host a proposed IP address, at least one server proposing an Internet Protocol (IP) address with a subnetwork ID identifying an LIS to which the host

was previously connected;

c. the host automatically selecting a proposed IP address according to an IP address of the desired LIS.

16. The method of claim 15, wherein the step of selecting includes selecting the IP address with the subnetwork ID identifying an LIS to which the host was previously connected.

17. The method of claim 15, wherein the step of sending further comprises:

a. sending the address request to an IP multicast address for a server having a certain IP scope; and

b. translating the address request into a call set-up message to the server using an ATM group address.

18. The method of claim 17, wherein the step of translating further includes translating the call set-up message to an IP autoconfiguration server using an ATM group address for an IP autoconfiguration service.

19. The method of claim 15, wherein the method further comprises after the step of selecting, the host sending a Dynamic Host Configuration Protocol (DHCP) discover message to the server that proposed the selected IP address.

20. The method of claim 15, wherein after selecting an IP address, the method further includes registering the IP address with an Address Resolution Protocol (ARP) server.

21. The method of claim 20, wherein the step of registering the IP address further comprises the host registering itself with the ARP server.

22. The method of claim 20, wherein the step of registering further comprises an autoconfiguration server supplying registration information to the ARP server whenever a new assignment is performed.

23. The method of claim 20, wherein the step of registering further comprises the ARP server polling the host at predetermined time intervals.

24. A method for semi-automatically configuring a host to a logical Internet Protocol (IP) Subnetwork, comprising the steps of:

a. the host sending an address request to at least one server attached to an asynchronous transfer mode (ATM) network;

b. each server receiving the request sending to the host a proposed IP address;

c. a user of the host manually selecting a proposed IP address according to an IP address of a desired LIS.

25. The method of claim 24, wherein the step of sending further comprises:

a. sending the address request to an IP multicast address for a server having a certain IP scope; and
b. translating the address request into a call set-up message to the server using an ATM group address.

26. The method of claim 25, wherein the step of translating further includes translating the call set-up message to an IP autoconfiguration server using an ATM group address for an IP autoconfiguration service.

27. The method of claim 24, wherein the step of contacting further comprises:

a. the host accessing a server having a restricted IP broadcast address; and
b. translating the message into a call set-up message to the server using an ATM group address.

28. The method of claim 24, wherein the method further comprises after the step of selecting, the host sending a Dynamic Host Configuration Protocol (DHCP) discover message to the server proposing the selected IP address.

29. The method of claim 24, wherein after selecting an IP address, the method further includes registering the IP address with an address resolution protocol (ARP) server.

30. The method of claim 29, wherein the step of registering the IP address further comprises the step of the host registering itself with the ARP server.

31. The method of claim 29, wherein the step of registering the IP address further comprises supplying registration information to the ARP server whenever a new assignment is performed.

32. The method of claim 29, wherein the step of registering the IP address further comprises the ARP server polling the host at predetermined time intervals.

33. A method for semi-automatically configuring a host to a logical Internet Protocol Subnetwork (LIS), comprising the steps of:

a. the host determining an IP subnetwork address of a desired LIS;

b. using the IP subnetwork address, the host contacting a configuration server in the desired LIS;

c. the configuration server assigning an Internet Protocol (IP) address to the host.

34. The method of claim 33, wherein the step of contacting the server further comprises generating an address discover message having a destination IP address which is an IP broadcast address for the desired LIS.

35. The method of claim 33, wherein the step of contacting further includes:

a. creating an Address Resolution Protocol packet having a resolving IP address that is an IP broadcast address and an option field indicating a configuration service is requested;

b. sending the packet to an ATM group address assigned to a server performing the address resolution service; and

c. contacting the configuration server using the resolved ATM address.

36. The method of claim 33, the step of contacting the server further comprises generating an address discover message having a route header destined to the IP subnetwork address of the desired LIS, and a destination IP address that is a multicast address assigned to a configuration service.

37. The method of claim 36, wherein the step of contacting further comprises:

a. creating an Address Resolution Protocol packet having a resolving IP address that is the IP route header and having an option field indicating a configuration service is requested;

b. sending the packet to an ATM group address assigned to a server performing an address resolution service; and

c. contacting the configuration server using the

resolved ATM address.

38. A method for supporting host mobility for a host moving from a first location to a second location in an Internet-over-ATM (asynchronous transfer mode) network, comprising the step of the host registering information about the second location with an address resolution protocol (ARP) server for the first location.

39. The method of claim 38 further comprising after the step of registering the ARP server forwarding communications for the host to the second location.

40. A method for supporting host mobility for a host moving from a home location connected to a first switch to a second location connected to a second switch in an Internet-over-asynchronous transfer mode network, comprising the steps of:

a. the host registering its home location with the second switch; and
b. the second switch informing the first switch that the host is located at the second location.

41. The method of claim 40, after the step of the second switch informing the first switch, the method further comprises:

a. the first switch receiving a communication addressed to the host;
b. the first switch generating a crank-back packet

indicating the host's location connected to the second switch; and

c. resending the communication addressed to the second switch.

42. The method of claim 41, wherein the step of resending further comprises resending the communication using DTL source routing.

FIG. 1
(PRIOR ART)

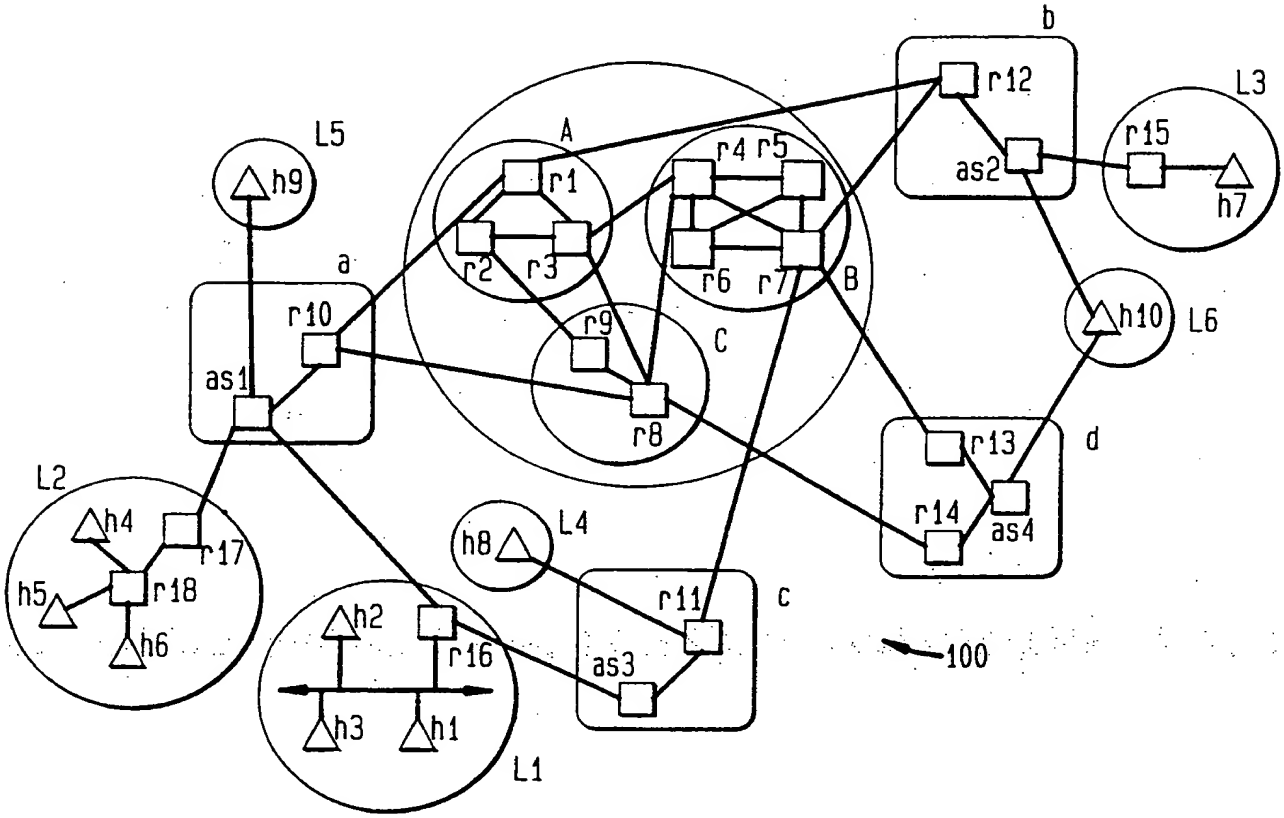


FIG. 2
(PRIOR ART)

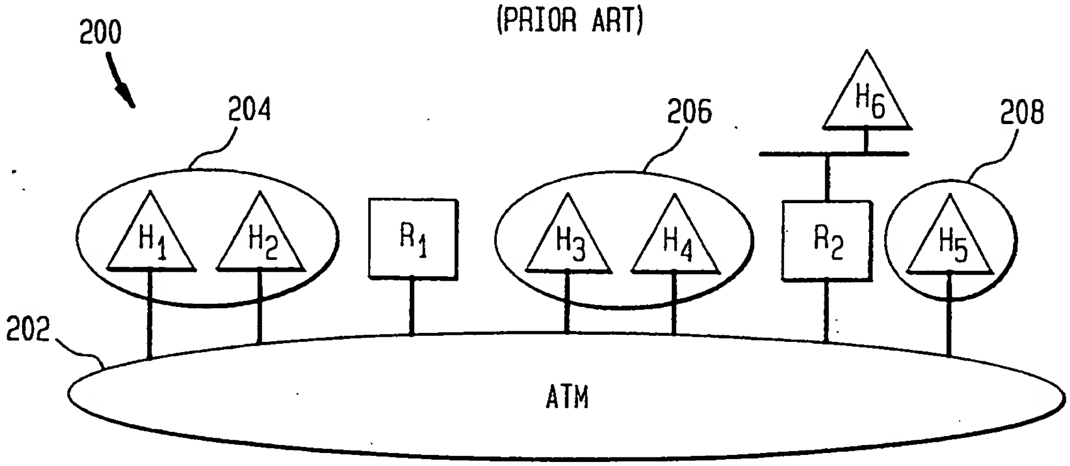


FIG. 3
(PRIOR ART)

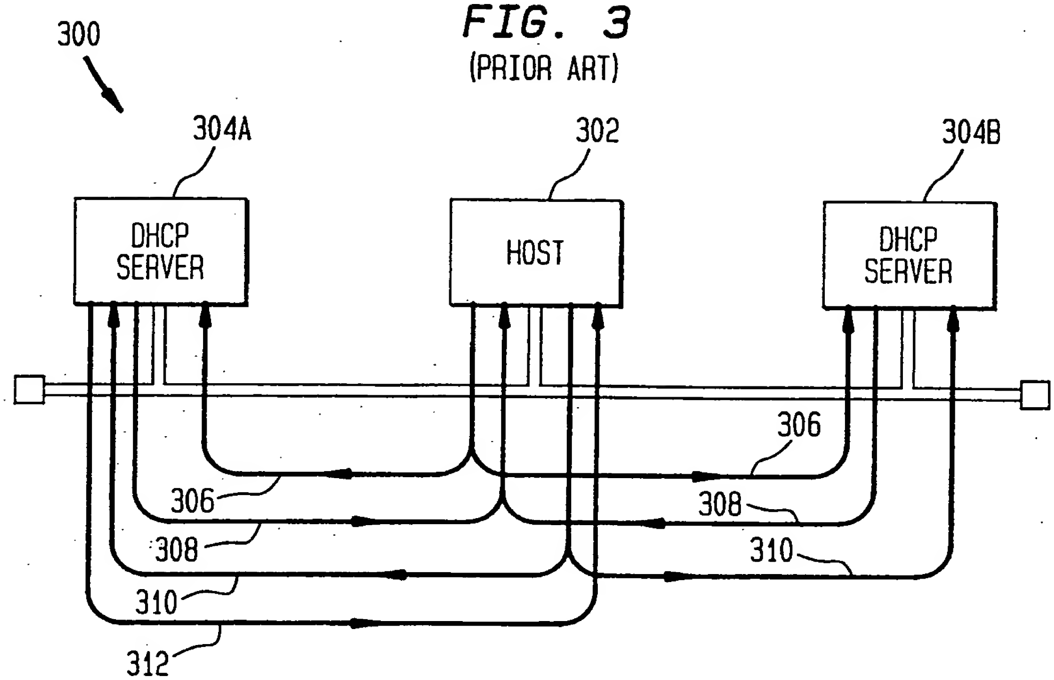


FIG. 4
(PRIOR ART)

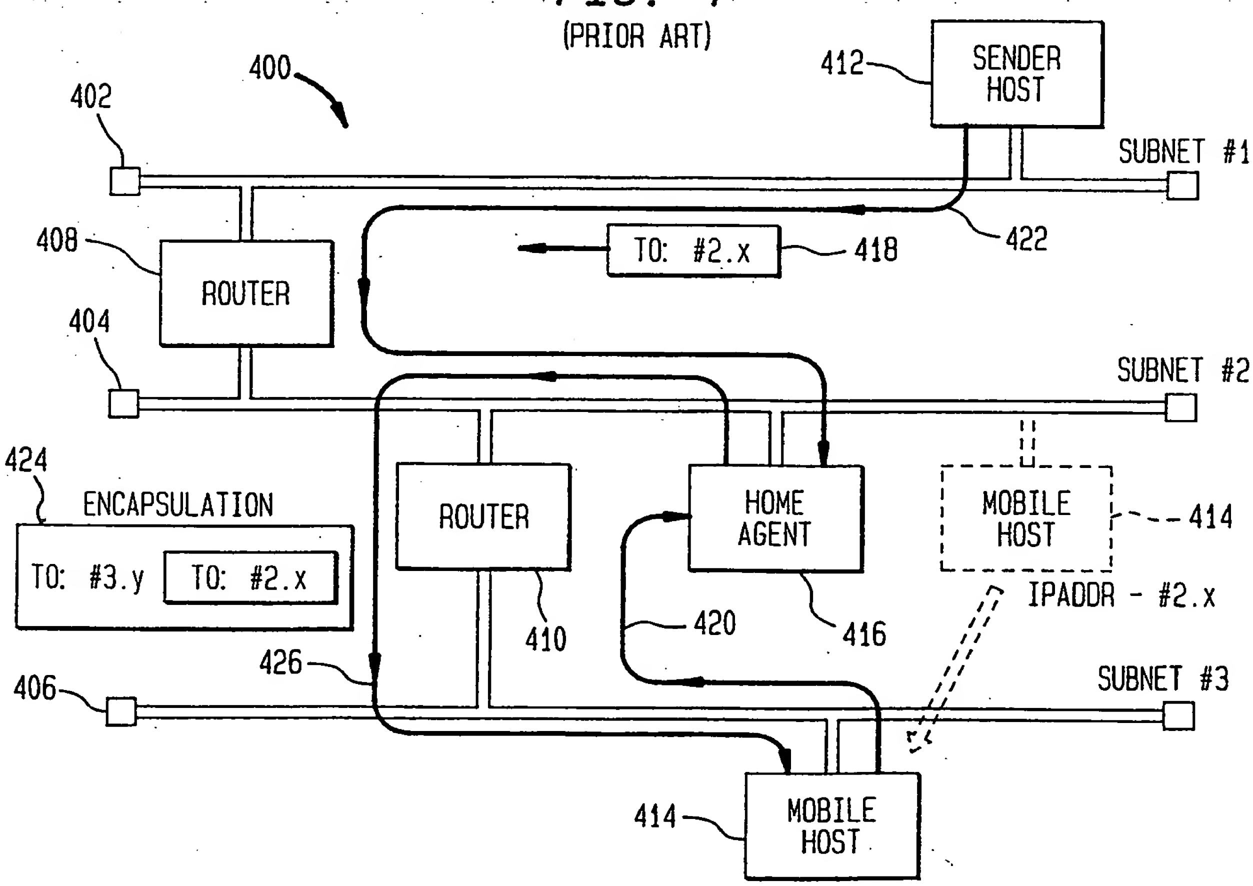


FIG. 5

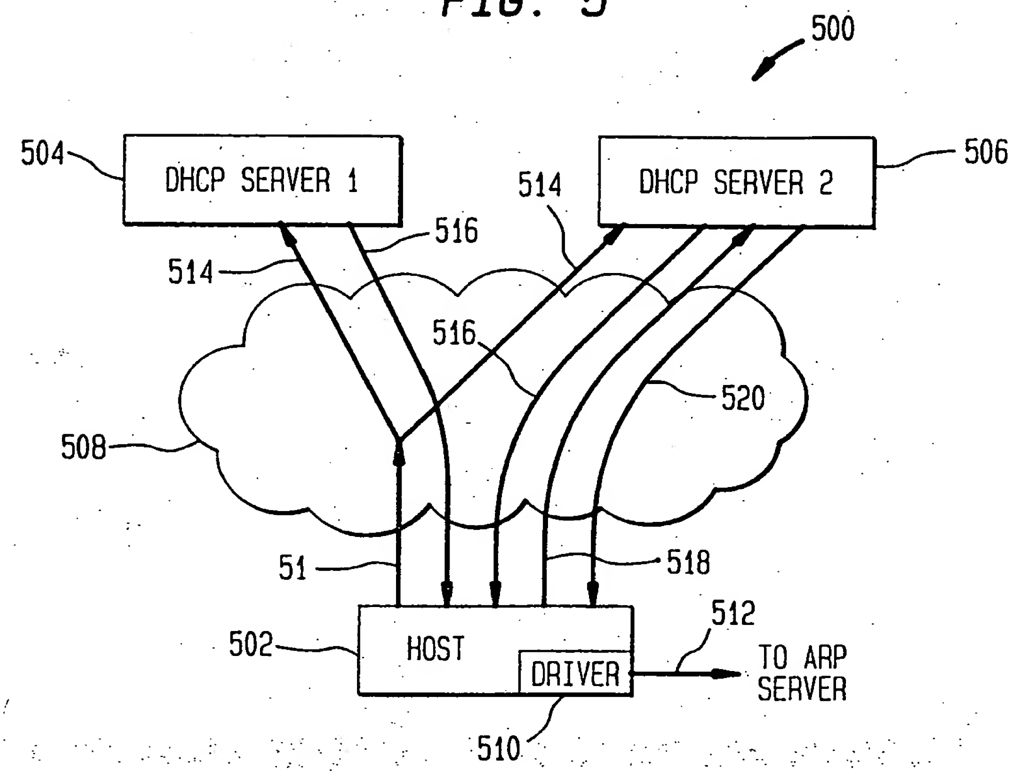

500
504
DHCP SERVER 1
506
DHCP SERVER 2
514
516
514
516
520
508
51
518
502
HOST
DRIVER
512
TO ARP SERVER
510

FIG. 6

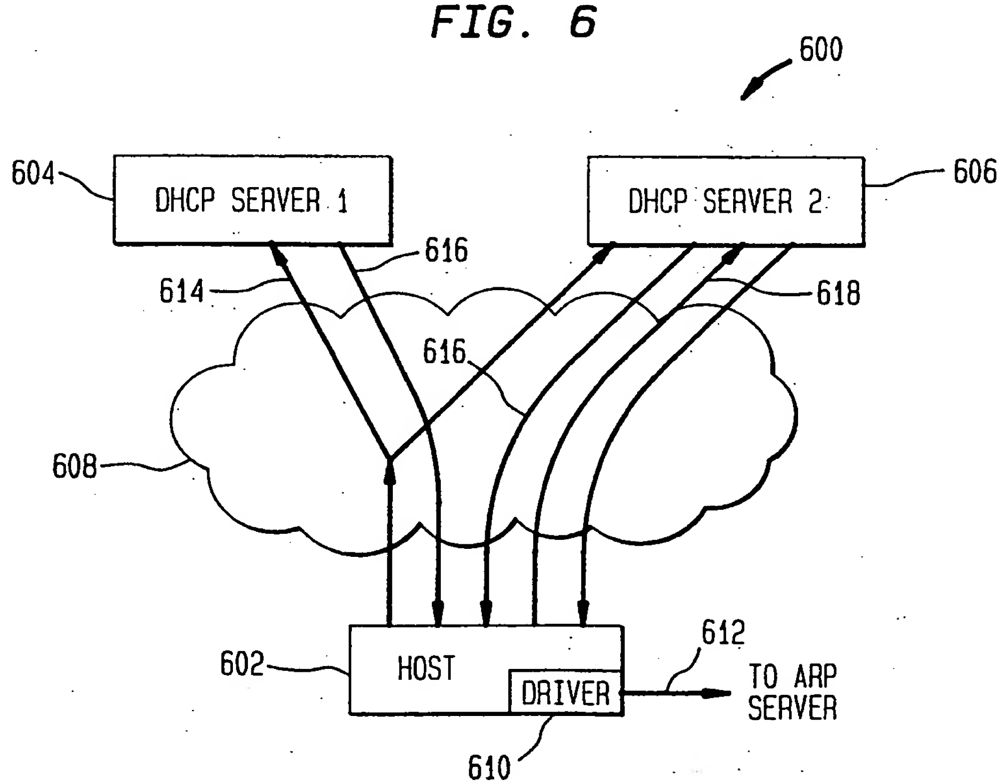

600
604
DHCP SERVER 1
606
DHCP SERVER 2
616
614
618
616
608
602
HOST
DRIVER
612
TO ARP SERVER
610

FIG. 7

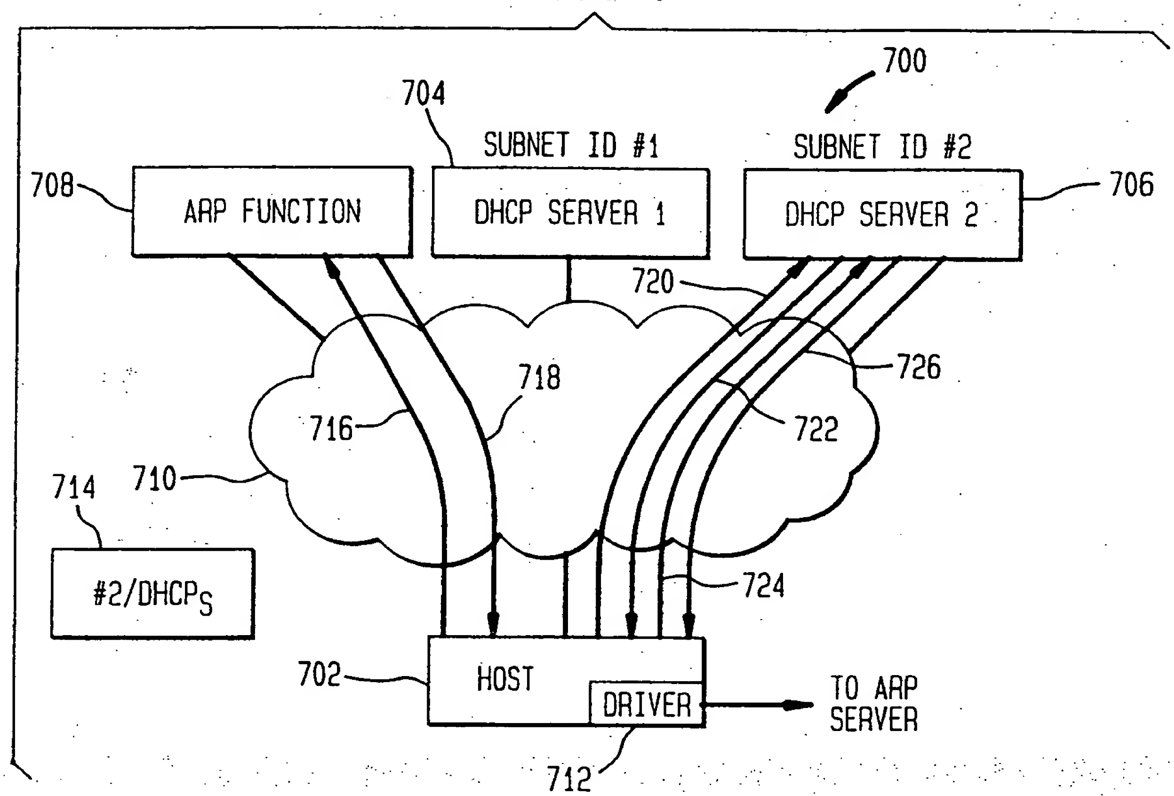

700
704
SUBNET ID #1
SUBNET ID #2
708
ARP FUNCTION
DHCP SERVER 1
DHCP SERVER 2
706
720
726
718
716
722
714
710
#2/DHCP$_S$
724
702
HOST
DRIVER
TO ARP SERVER
712

FIG. 8

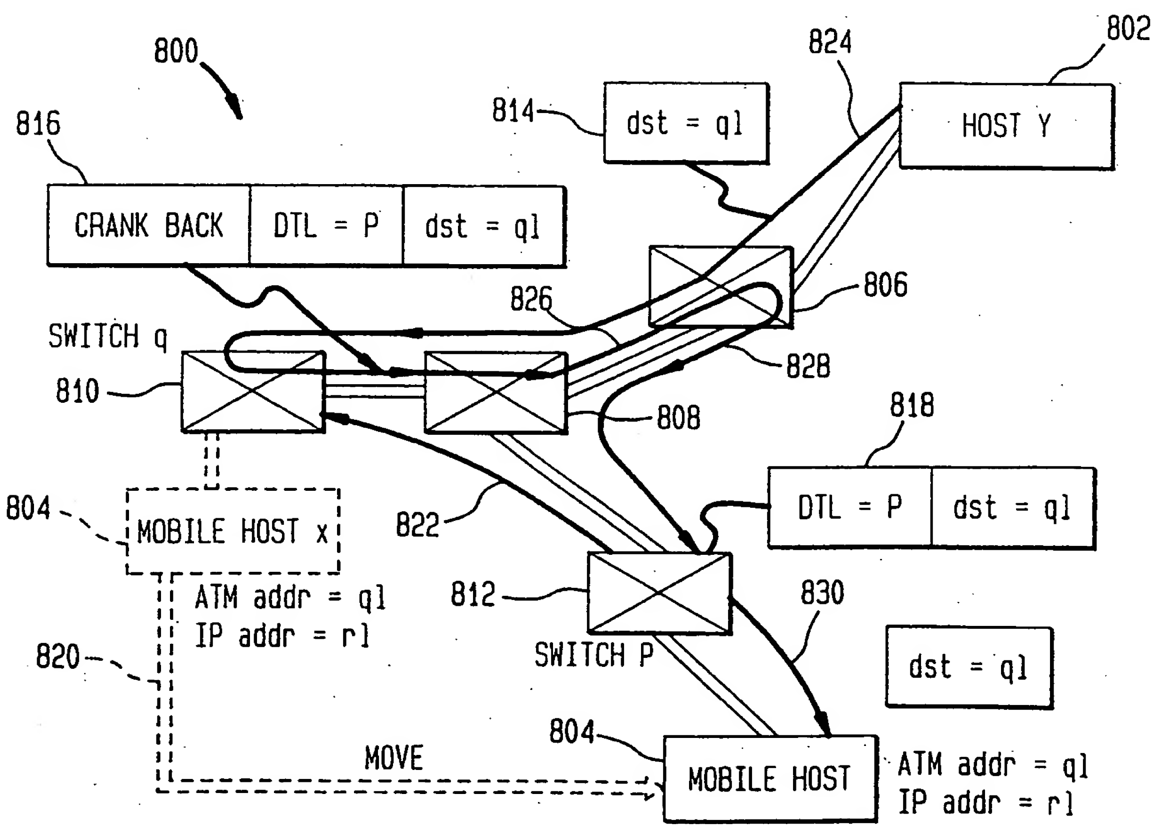

800
824
802
814
dst = ql
HOST Y
816
CRANK BACK
DTL = P
dst = ql
826
806
SWITCH q
828
810
808
818
804
MOBILE HOST x
822
DTL = P
dst = ql
ATM addr = ql
IP addr = rl
812
830
SWITCH P
dst = ql
820
804
MOVE
MOBILE HOST
ATM addr = ql
IP addr = rl

FIG. 9

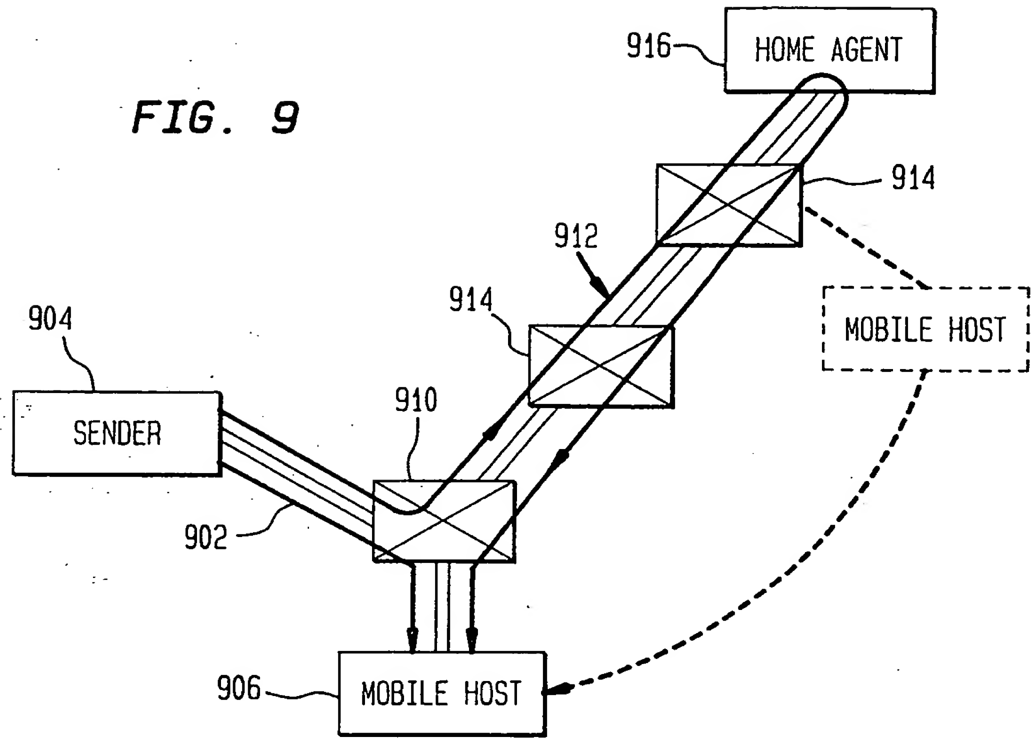


FIG. 10A

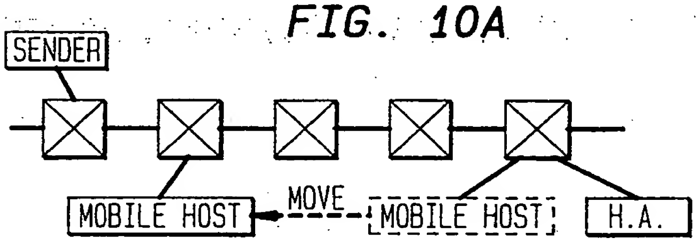


FIG. 10B

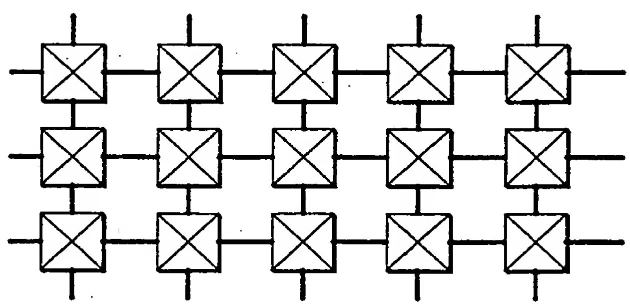


FIG. 10C

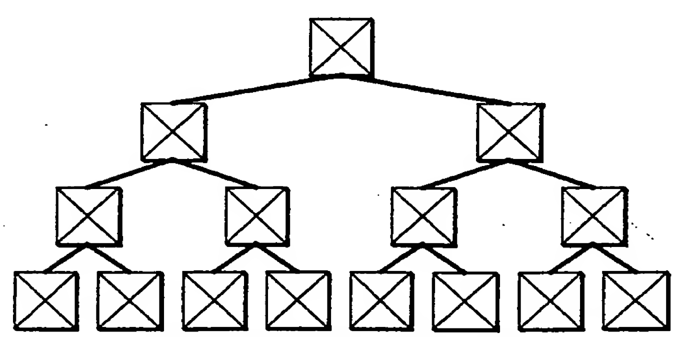


FIG. 11

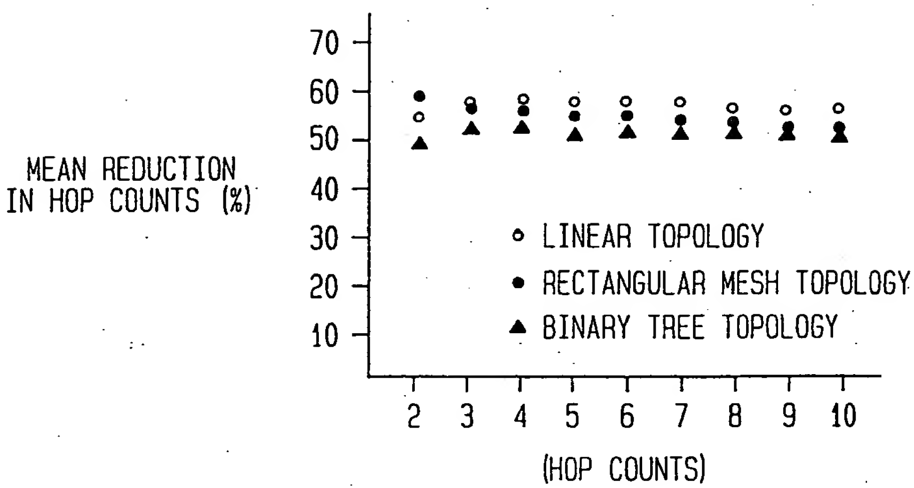

MEAN REDUCTION IN HOP COUNTS (%)
70
60
50
40
30
20
10
LINEAR TOPOLOGY
RECTANGULAR MESH TOPOLOGY
BINARY TREE TOPOLOGY
2 3 4 5 6 7 8 9 10
(HOP COUNTS)

FIG. 12

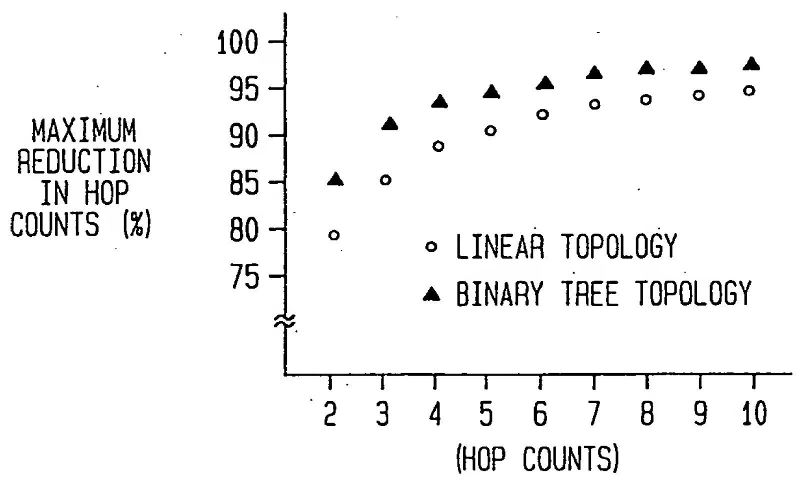
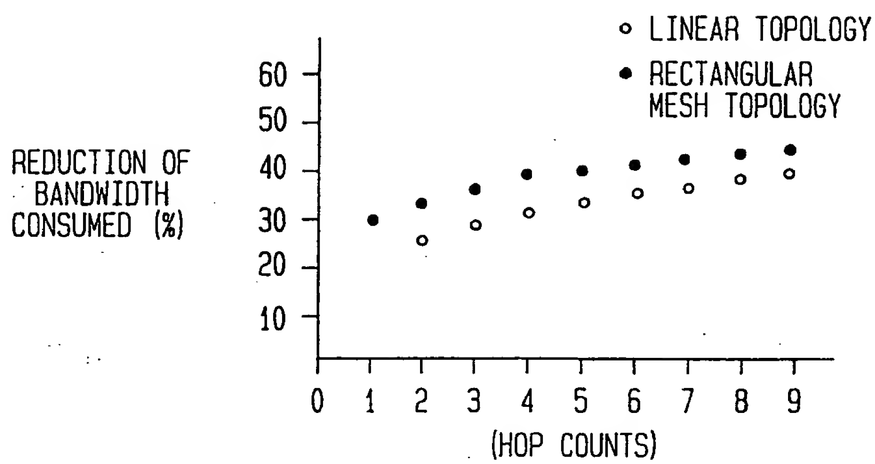
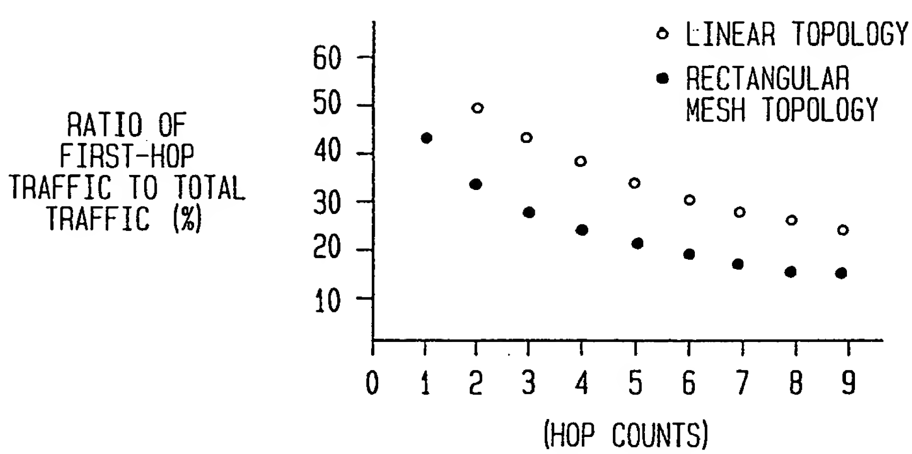

MAXIMUM REDUCTION IN HOP COUNTS (%)
100
95
90
85
80
75
LINEAR TOPOLOGY
BINARY TREE TOPOLOGY
2 3 4 5 6 7 8 9 10
(HOP COUNTS)

FIG. 13



○ LINEAR TOPOLOGY
● RECTANGULAR MESH TOPOLOGY
REDUCTION OF BANDWIDTH CONSUMED (%)
60
50
40
30
20
10
0 1 2 3 4 5 6 7 8 9
(HOP COUNTS)

FIG. 14



○ LINEAR TOPOLOGY
● RECTANGULAR MESH TOPOLOGY
RATIO OF FIRST-HOP TRAFFIC TO TOTAL TRAFFIC (%)
60
50
40
30
20
10
0 1 2 3 4 5 6 7 8 9
(HOP COUNTS)